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Liverpool Marine Biology Committee.

L.M.B.C. MEMOIRS

ON TYPICAL BRITISH MARINE PLANTS & ANIMALS

EDITED BY W. A. HERDMAN, D.Sc., F.R.S.

IV.

CODIUM

BY

R. J. HARVEY GIBSON, M.A., F.L.S.,

Professor of Botany in University College, Liverpool

AND

HELEN P. AULD, B.Sc.,

University Scholar in Botany

(With 3 Plates)

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L.M.B.C. MEMOIRS

IV.

CODIUM

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EDITOR'S PREFACE.

The Liverpool Marine Biology Committee was constituted in 1886, with the object of investigating the Fauna and Flora of the Irish Sea.

The dredging, trawling, and other collecting expeditions organised by the Committee have been carried on intermittently since that time, and a considerable amount of material, both published and unpublished, has been accumulated. Thirteen Annual Reports of the Committee and four volumes dealing with the "Fauna and Flora" have been issued. At an early stage of the investigations it became evident that a Biological Station or Laboratory on the sea-shore nearer the usual collecting grounds than Liverpool would be a material assistance in the work. Consequently the Committee, in 1887, established the Puffin Island Biological Station on the North Coast of Anglesey, and later on, in 1892, moved to the more commodious and convenient Station at Port Erin in the centre of the rich collecting grounds of the south end of the Isle of Man.

In these twelve years experience of a Biological Station (five years at Puffin Island and seven at Port Erin), where College students and young amateurs formed a large proportion of the workers, the want has been constantly felt of a series of detailed descriptions of the structure of certain common typical animals and plants, chosen as representatives of their groups, and dealt with by specialists. The same want has probably been felt in other similar institutions and in many College laboratories.

The objects of the Committee and of the workers at the Biological Station have hitherto been chiefly faunistic and speciographic. The work must necessarily be so at first when opening up a new district. Some of the workers have published papers on morphological points, or on embryology and observations on life-histories and habits; but the majority of the papers in the volumes on the "Fauna and Flora of Liverpool Bay" have been, as was intended from the first, occupied with the names and characteristics and distribution of the many different kinds of marine plants and animals in our district. And this faunistic work will still go on. It is far from finished, and the Committee hope in the future to add greatly to the records of the Fauna and Flora. But the papers in the present series are quite distinct from these previous publications in name, in treatment, and in purpose. They will be called the "L.M.B.C. Memoirs," each will treat of one type, and they will be issued separately as they are ready, and will be obtainable Memoir by Memoir as they appear, or later bound up in convenient volumes. It is hoped that such a series of special studies, written by those who are thoroughly familiar with the forms of which they treat, will be found of value by students of Biology in laboratories and in Marine Stations, and will be welcomed by many others working privately at Marine Natural History.

It is proposed that the forms selected should, as far as possible, be common L.M.B.C. (Irish Sea) animals and plants of which no adequate account already exists in the text-books. Probably most of the specialists who have taken part in the L.M.B.C. work in the past, will prepare accounts of one or more representatives of their groups. The following have already promised their services, and in many cases the Memoir is already far advanced. The

first Memoir appeared in October and the second in December, 1899, the third in February, 1900, and this fourth one will be issued early in April: others will follow, it is hoped, in rapid succession.

Memoir I. Ascidia, W. A. Herdman, 60 pp., 5 Pls., 1s. 6d.
II. Cardium, J. Johnstone, 92 pp., 7 Pls., 2s.
III. Echinus, H. C. Chadwick, 36 pp., 5 Pls., 1s. 6d.
IV. Codium, R. J. H. Gibson and Helen Auld, 1s.
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Calcareous Sponge, R. Hanitsch.
Arenicola, J. H. Ashworth.
Antedon, H. C. Chadwick.
Oyster, W. A. Herdman and J. T. Jenkins.
Porpoise, A. M. Paterson.

In addition to these, other Memoirs will be arranged

for, on suitable types, such as *Sagitta* (probably by Mr. Cole), *Carcinus*, an Amphipod, and a Pycnogonid (probably by Mr. A. R. Jackson).

As announced in the preface to ASCIDIA, a donation from Mr. F. H. Gossage of Woolton met the expense of preparing the plates in illustration of the first few Memoirs, and so enabled the Committee to commence the publication of the series sooner than would otherwise have been possible. A second donation recently received from Mr. Gossage is regarded, by the Committee, as a welcome encouragement, and will be a great help in carrying on the work.

W. A. HERDMAN.

University College, Liverpool,
April, 1900.

L.M.B.C. MEMOIRS.

No. IV. CODIUM.

BY

R. J. Harvey Gibson, M.A., F.L.S., and Helen P. Auld, B.Sc.

Introduction.

Among the heterogeneous collection of Algæ, marine and fresh-water, known to Botanists as Chlorophyceæ, none, perhaps, are more interesting from the morphological point of view than the Siphoneæ. The interest attaching to them centres in the fact that the vegetative thallus, though not infrequently of immense size and complicated structure, is, in reality, produced by the extension, branching and modification of a single "cell" or cœnocyte, possessed of an indefinite number of nuclei. In such forms as *Valonia*, the primitive spherical cell form is retained; in *Vaucheria*, the thallus becomes filamentous and sparingly branched; in *Caulerpa*, *Bryopsis*, &c., the branching is more extensive and symmetrical. In other types, again, the thallus consists of an aggregation of hyphæ, held together by a deposition of calcium carbonate, *e.g.*, *Halimeda*, &c., by holdfasts of diverse form, *e.g.*, *Udotea*, *Struvea*, &c., or by intimate interweaving of the filaments themselves, a mode of union illustrated by the subject of the present Memoir, viz., *Codium*.

Since the L.M.B.C. Memoirs are primarily intended for the use of "students of Biology in our laboratories and in marine stations," or "working privately at natural history," it may be advisable to summarise briefly the main features of the British marine Siphoneæ, and more especially the Codiaceæ, at the same time indicating the general distribution of the species on our shores.

The British representatives of the Siphoneæ include members of five different orders, viz.: Bryopsidaceæ, Derbesiaceæ, Vaucheriaceæ, Valoniaceæ, and Codiaceæ. According to Holmes and Batters (A Revised List of the British Marine Algæ, *Ann. of Botany*, V., 1890) four of these orders are represented in our flora by one genus apiece—in each case by the genus that gives the name to the order. In regard to the fifth, the Valoniaceæ, it may be noted that the genus inhabiting British seas, viz., *Halicystis*, had not been discovered at the date of the publication of Holmes' and Batters' paper.

I. Bryopsidaceæ.

The thallus in this order is freely branched in a pinnate manner and anchored to the substratum by rhizoids which are extensions of the base of the chief axis. The branching of the thallus may be bi- or tri-pinnate. Multiplication is effected by the conjugation of dissimilar gametes. The female gametes are large and green, the male are small and brownish yellow. Both are provided with two cilia. The actual fusion of the gametes has not yet been observed. No other method of propagation is known in the order.

The Bryopsidaceæ include only one genus, *Bryopsis*, with about 25 species, chiefly inhabitants of warm seas. In British seas two species occur, *B. hypnoides*, Lamx., an inhabitant of the English Channel, and *B. plumosa*, C. Ag.,

which occurs in the same area but on the coasts of the Irish Sea also. *B. hypnoides* is recorded from the Isle of Man and Puffin Island, Anglesea, but requires confirmation; *B. plumosa* is fairly common in rock pools in the L.M.B.C. area.

II. Derbesiaceæ.

This order also includes only one genus, *Derbesia*, with about 8 species, according to Wille (Engler and Prantl, *Pflanzen-familien*). The thallus is simple, irregularly or dichotomously branched, and produces spherical swarm-spores in lateral zoosporangia. Each zoospore is provided with a circlet of cilia, surrounding the bluntly pointed hyaline apex.

Derbesia tenuissima, Crn., is recorded from the English Channel, but it has not as yet been discovered in the L.M.B.C. area.

III. Vaucheriaceæ.

This order also is represented by only one genus, *Vaucheria*, and embraces about 25 species, which are inhabitants of fresh or brackish water. Whilst vegetatively not unlike *Derbesia*, *Vaucheria* differs markedly in its methods of reproduction from the rest of the Siphoneæ. In addition to considerable powers of vegetative multiplication, solitary zoospores (zoocœnocytes) are developed in sporangia formed by the abstriction of the terminal portions of vegetative branches. Sexual organs in the form of ovoid oogonia and filamentous antheridia also occur as lateral branches of the filamentous thallus. Fertilisation of the solitary ovum takes place within the oogonium, the oosperm developing into a new *Vaucheria* filament after a period of hibernation.

Five species, with several varieties, are found on British

coasts, but only two of these, *V. dichotoma*, Lyngb., var. *marina*, C. Ag., and *V. thuretii*, Woron., have been definitely identified in the L.M.B.C. area.

IV. Valoniaceæ.

The thallus in this order retains its primitive cellular form or is branched, but shows no differentiation into axis and appendages. The sporangia are formed directly from portions of the vegetative thallus.

One genus only occurs in the British Algal Flora, viz., *Halicystis*, included by Wille (*loc. cit.*) under *Valonia*. *H. ovalis* was first discovered by Murray and Schmitz in Loch Goil, in the Clyde Sea Area, in 1892, but later it was found by Robertson at Lamlash, Arran (vide *Phycological Memoirs*, Pt. II., and *Journal of Bot.*, vol. XXXII., p. 345).

V. Codiaceæ.

The Codiaceæ include 8 genera, viz.: *Chlorodesmis*, *Penicillus*, *Aurainvillea*, *Rhipocephalis*, *Callipsygma*, *Udotea*, *Halimeda*, and *Codium*. The last named alone occurs in English waters.

The thallus of the Codiaceæ is of varied form and organisation; some genera, *e.g.*, *Halimeda*, being incrusted with calcium carbonate. The filaments of which the thallus is composed are profusely branched, and the branches are closely interwoven and bound together in such a manner as to form almost a definite tissue. Generally speaking, the filaments so woven together form a medullary region from which arise short swollen branches, standing at right angles to the long axis of the thallus, and forming a superficial limiting layer, the so-called "palisade layer" or "tissue." From the sides of these "palisade cells" arise the sporangia or

gametangia, from which are derived swarmspores or gametes.

Three species of *Codium* (out of fifteen) occur in British seas, but only one, *C. tomentosum*, occurs in the L.M.B.C. district.

Codium.

The genus *Codium* was first established by Stackhouse (*Ner. Brit.*, 1795—1801), to receive the type previously known as *Fucus tomentosus*. This name the same authority altered to *Lamarkea* in the second edition of his work, and included under it two species *C. tomentosum* and the plant now known as *C. bursa*. Lamouroux, in 1813, proposed the name *Spongodium* for the genus, whilst, later still, Cabrera re-christened these and other species by placing them in the newly constituted genus *Agardhia*. C. Agardh reverted to the name suggested by Stackhouse, and, at the same time, re-defined the genus. Decaisne subsequently sub-divided the then known species into two genera, one represented by *Codium tomentosum*, for which he retained the name of *Codium*, the other represented by *Codium bursa*, to which he gave the name of *Spongodium*.

An elaborate and authoritative account of the genus was, in 1885, published by the great Swedish Algologist, J. A. Agardh (Till Algernes Systematik, *Lunds Univ. Årsskr.*, XXIII.). In this monograph he includes all previously known species under the single generic heading of *Codium*, sub-dividing them, however, into tribes, which are, on the whole, co-extensive with the genera established by preceding authors.

The first tribe established by Agardh is that represented by *Codium adhærens*, Cabr., where the thallus is firmly fixed to the substratum in the form of a dark green, gela-

tinous expansion, with marginal lobes. This type naturally leads up to that of *Codium bursa*, Turn., where the thallus is globular, but fixed to the substratum by an extended base, the centre of the mass being filled with a loose network of filaments. The third series is represented by the species dealt with in the present Memoir, viz., *Codium tomentosum*, Stackh. In this series the thallus is cylindrical and elongated, and branched more or less dichotomously. Finally, Agardh establishes a series based on the species *Codium elongatum*, C. Ag., where the branches are flabellate.

The majority of the species of *Codium* are included in the third series, and these are by Agardh sub-divided again into two sections, dependent on the form of the lateral branches of the hyphæ, which form the superficial palisade layer. These lateral branches, named "utricles" by Agardh, are, according to him, either (*a*) smooth and rounded at their apices, or (*b*) furnished with an apical umbo or point. Under the former Agardh includes *C. tomentosum*. A careful examination of the palisade layer of that species will show, however, that this distinction cannot be rigidly maintained, for some of the palisade processes are smooth, whilst others are distinctly mucronate (see Pl. I., fig. 3).

Enough has now been said to indicate the taxonomic position of the species under consideration, and to define its general relationship to other Chlorophyceæ.

Distribution.

Codium tomentosum, the oldest known species of the genus, is widely distributed in the marine waters of the globe. If we accept Agardh's view, the species is a native of the shores of the Atlantic Ocean. On the west it occurs especially on the shores of Florida and the Antilles,

and on the east from the British Islands to the Cape of Good Hope. It is also found on the shores of the Mediterranean and Adriatic. Harvey (*Ner. Bor. Amer.*, III., p. 29, and *Phyc. Brit.*, vol. IV.), however, considers it to have a much wider range, by including under the species forms which are by other authors, and amongst these Agardh, ranked as distinct species. If we accept Harvey's view, then its distribution would be "all the shores of Europe, both Mediterranean and Atlantic. Dispersed also throughout the temperate and torrid portions of the Atlantic, Pacific, and Indian Oceans. New Holland and Tasmania. Auckland Islands."

Locally, so far as we have been able to find out, *Codium tomentosum* has been recorded from one situation only, namely, the south end of the Isle of Man. It occurs in shallow rock pools at or near low water mark, at Port Erin and at Fleswick Bay. From these regions our material was obtained fresh, and kept growing in salt-water tanks in the Laboratory. The plants are perennials, and fruit freely (at all events, in these localities) in winter. The time for fruiting is generally given as November. Plants sent to us in February had abundant fruit. We have not as yet had the opportunity of examining material collected at any other period of the year. Most of the sporangia had shed their contents by March.

General Morphology.

Plants of *Codium tomentosum* most commonly grow in more or less dense clusters, arising from a basal expansion which is intimately connected with and attached to the substratum, rock, sand, or broken shell debris (Pl. I., fig. 1). The erect shoots are branched and cylindrical. The branching is usually dichotomous but occasionally monopodial. The branches vary in thickness, but in a well

grown plant average from $\frac{1}{4}$ to $\frac{3}{8}$ of an inch in diameter, narrower at the base and swelling out somewhat at the apex. The apices of the branches are obtuse and much darker in colour than the rest of the plant. Occasionally the fronds are somewhat compressed. In length they vary greatly. We have found, after examination of a large number, that a well grown plant (in this district) is on an average from 8 to 10 inches long, but Harvey speaks of them as sometimes reaching a length of 2 feet. The plant he figures, however (*Phyc. Brit.*, Pl. XCIII.), is under 8 inches in length, so that our plants may be taken as of normal size for the British Islands.

In colour *Codium tomentosum* is a rich dark green, intensely so near the apices of the branches—so dark, indeed, as to appear almost black. This will be found to be due to, first, the closer packing of the superficial palisade "cells" in these localities, and secondly, to the aggregation of the chloroplastids in the apices of the palisade "cells" themselves. The green is not so intense nearer the base. In substance the plant, when fresh, is fairly firm and rigid, and, externally, soft and slippery to the touch; but after preservation in alcohol it becomes soft and flaccid.

Anatomy.

A. Vegetative Organs.

The thallus consists essentially of densely woven branched hyphæ, forming a central core or medulla, from which arise very numerous short and thick branches, standing at right angles to the long axis of the branch and closely packed so as to form a velvety pile covering the entire surface.

The plant is attached to the substratum, as already stated, by numerous rhizoids. The rhizoids are branched

and contain a few chloroplasts and a delicate protoplasmic lining. They do not, indeed, differ from the general hyphæ, of which the main mass of the plant is composed. Each has a definite and fairly thick wall, and several nuclei in the peripheral lining of protoplasm. The rhizoidal, as well as the medullary hyphæ, are sub-divided at intervals by the formation of annular thickenings on the inside of the walls. The annulus gradually increases until the lumen is completely occluded. Such occlusion is figured at fig. 2, Pl. I.; figs. 10 and 14, Pl. II.; figs. 17, 18, and 19, Pl. III.

The chloroplasts in the plant generally are very minute and extremely numerous, and usually associated in strings or clusters, especially in the lateral palisade branches.

The nuclei, described first by Arcangeli (Sul alcune Alghe del gruppo delle Celoblastee, *Nuova gior. bot.*, VI.), but not known to him as nuclei, have been the subject of investigation by Schmitz (*Sitz. d. natur. Gesell. zu Halle*, 1878) and Berthold (Zur Kenntnis der Siphoneen und Bangiaceen, *Mitt. Zool. Stat. Neapel*, 1880). We have not ourselves followed the division of the nuclei, and so incorporate a brief abstract of Berthold's observations.

Berthold studied the division of the nuclei in the palisade "cells" where, in the basal region, owing to the small number of chloroplasts, they can be easily made out. He found them to be much flattened, oval or elliptical in outline, and sometimes pointed at one end. Each contains two or three nucleoli. The nuclei are usually about 15 μ in length and 6 μ broad, and each possesses a clearly defined nuclear membrane. Berthold was unable to study the very earliest stages in the division, but the phenomena observed from an early stage to the end of the division occupied from 3 to 4 hours. During the entire

period the nucleus remained clearly demarcated from the surrounding protoplasm. The nucleus is at first spindle shaped, a form which it retains for as much as half the period of division. The only alterations visible are at the apices of the spindle, which are at times blunter, at other times more pointed. Presently the spindle becomes flatter and shorter, the apices swell, and the central region contracts slightly. The nucleus has then a dumb-bell form. Later on the median part begins to swell, whilst the lateral parts adjoining the new nuclei become reduced to fine threads. Finally, the connection is broken in the neighbourhood of one of the new nuclei, but the connecting region is not absorbed into the other nucleus, as might be expected. On the other hand, a further separation between the second nucleus and the median connecting band takes place, and the intermediate region is thrown off and finally disappears. In the spindle stage, Berthold made out clearly filaments passing through the mass, having the nucleoli between them, and also certain granules which he considers as the equivalent of a nuclear plate. When the spindle elongates and the poles swell, the filaments thicken, and their substance is gradually transferred into the swollen ends. Berthold was unable to observe any movement in the surrounding plasma during division. (See also Zimmermann, *Die Morph. u. Phys. des pflanzlichen Zellkernes.* Jena. 1896.)

The rhizoids are continuous with the medullary region of the plant, which is composed of intimately interwoven branched filaments, forming a "tissue," not unlike a fungus mycelium. Numerous partitions, of the nature already described, occur in the course of the hyphæ, dividing the filaments up into multi-nucleate pieces, comparable to the segments of a *Cladophora* filament.

As the hyphæ become erect they proceed to give off

outwardly the palisade branches. These branches are several times the breadth of the hypha from which they arise. Each has a narrow base, its cavity sometimes separated from the hypha by a partition. More commonly the partition occurs on the hypha itself just before the palisade process is given off. The palisade "cell" rapidly thickens, and finally ends in a swollen rounded head (Pl. I., fig. 3), or more commonly, retains a uniform diameter for the upper third of its length, and ends in a bluntly rounded manner. The apex is in many cases quite smooth, but in other cases is distinctly mucronate. The wall of the cell at the apex is much thicker than elsewhere, especially so at the extreme tip. The palisade cell contains protoplasm distributed in a thin layer over the wall, with fine strands traversing the cavity. Towards the apex, however, the protoplasm is more abundant, and finally becomes aggregated in a non-vacuolated mass just at the apex itself. The chloroplasts, which are very numerous, are collected into a dense layer or mass, just at the apex, but occur also scattered in rows and clusters in the peripheral protoplasmic layer.

On teasing out a portion of a very young plant, one is able to see the relationship of the medullary hypha and the lateral processes more clearly. Figure 11, Pl. II., shows the terminal portion of a superficial medullary hypha, which has given off a lateral "palisade cell," now nearly mature, and which is forming two lateral processes acropetally, destined to become "palisade cells." It will be observed that the thickenings or septa are formed very early, and behind the point of origin of each process. Figures 10 and 14 show two septa in an older filament. The wall is double, and the septum is seen to be due to secondary deposit on the inner layer. For a long time protoplasmic continuity is maintained; indeed, it was

only in very old septa that we were unable to demonstrate the presence of stainable substance in the channel. Finally the lumen becomes completely obliterated.

B. Reproductive Organs.

The reproductive organs of Codium have been the subject of investigation by several algologists.

Thuret (Recherches sur les zoospores des Algues, *Ann. Sc. Nat., 3e. Sér., Bot.* XIV.) showed that oval sporangia were formed from the upper parts of the swollen palisade "cells," each giving rise to biciliate swarmspores which, he affirmed, developed directly into new basal filaments.

Derbes and Solier (Mémoire sur quelques points de la physiologie des Algues, *Súppl. des Comp. Rend.*, 1856) describe the formation of the sporangia and state that they become separated from the parent filament by a partition. The internal green mass resolves itself into zoospores which escape *en masse*, afterwards separating from each other, swimming actively apart. The authors were unable to determine the cilia, nor did they follow out the subsequent history of the zoospore. Schmitz *(loc. cit.)* added some notes on the nuclei of the zoospores.

In 1880 Berthold confirmed the occurrence of biciliate zoospores, but did not succeed in getting them to germinate. On the other hand, he affirms the existence of minute yellow biciliate swarmspoores formed in quite similar sporangia, and he states that he succeeded in obtaining young plants only when both kinds of fructification were present.

Lastly, Went (Les modes de Reproduction du *Codium tomentosum*, *Vergad. der Ned. Bot. Vereen.*, 1889) re-investigated the question and added new facts. He confirms Berthold on the question of the existence of large green zoospores and small yellow ones, but he states that, con-

trary to Berthold's observations, both kinds of sporangium occur on the same plant. He further states that he obtained young plants from the mega-zoospores alone.

Perhaps the most interesting point in Went's paper is his discovery of the fact that the sporangium may, instead of developing zoospores, germinate itself directly into a new filament, branching even whilst still attached to the parent "palisade cell." Went terms these "abnormal sporangia," and suggests the possibility of their being galls due to the presence and stimulating action of Rotifera, just as the Rotifer *Notommata* produces galls in *Vaucheria*. He admits, however, that he saw no evidence for the presence of any parasite.

Turning now to our own observations, we find that the sporangia are produced plentifully during the winter months, and are in the form of much elongated ovate bodies arising from the sides of the upper half of the "palisade cells" (Pl. III., figs. 15, 17, 18; Pl. II., fig. 5). Usually one sporangium is borne on each "palisade cell," but there may be a succession from the same cell, as is evidenced by the existence of scars indicating the points of attachment of older sporangia (Pl. II., fig. 5, and Pl. III., fig. 18). In other cases two or even three sporangia may occur together (Pl. II., fig. 5, and Pl. III., fig. 17). Each sporangium as it ripens becomes separated from the parent palisade process by an annular septum similar to those found in the vegetative part of the thallus. The wall of the sporangium is distinctly two layered, the outer layer being thin and well defined, the inner somewhat thicker and capable of swelling considerably. For the most part the two layers are in close approximation, but at the base and also at the apex they separate when the sporangium becomes mature. In fig. 15, Pl. III., a ripe sporangium is illustrated, where it will be seen that the inner wall is

distinctly separated from the outer at the base, leaving a small chamber between the plug-like septum and itself (compare fig. 20, Pl. III.). Similarly, at the apex of the sporangium, a like chamber is formed, and the inner wall itself, as shown in fig. 16, swells and exhibits very definite lamellation. The occurrence of these cavities at the base and apex of the sporangium was obviously noted both by Derbes and Solier and by Harvey, for their figures of the sporangium illustrate, though somewhat roughly, the peculiarity to which we draw attention. The sporangial cavity is from half to three quarters full of a dark green mass which, on careful focussing, is seen to be composed of spherical bodies, each crammed with chloroplasts.

Notwithstanding the fact that we examined hundreds of sporangia for long periods, and extending over three months, only once were we so fortunate as to see the zoospores escape. As described by Derbes and Solier, they escaped *en masse*, the apex of the sporangium rupturing suddenly, probably owing to pressure exerted from within by the swollen inner layer of the sporangium wall. The green mass gradually dissolved in the sea-water (in which, of course, the observations were made), and individual zoospores freed themselves and swam off. The zoospores were dark green, with a clear apex, and showed, in the apical region, a body which was doubtless the nucleus described by Berthold. Each was provided with two cilia. We were unable to keep the zoospores alive until germination had ensued, though we purpose repeating our observations in the hope of solving the question as to whether they are zoospores or gametes, as Berthold believes.

The sporangium is, early in its development, isolated from the palisade cell by an annular thickening in its narrow pedicel (Pl. III., fig. 20). This thickening becomes finally a complete plug, and after the contents of the

sporangium have been ejected, it suffers transverse rupture. The empty sporangium is cast off, and there is left a scar on the side of the "palisade cell" (Pl. III., fig. 18).

On the same plant we have found longer and narrower "sporangia" (Pl. II., fig. 7) with orange-green contents, which we believe to be the young stages of the microsporangia described by Berthold. This author gives no figure of these bodies, although he says they are quite similar to those containing the larger green swarm-spores. These gametangia (?) we found in all stages of development. They possess the same characters as the sporangia, save that they are much longer and narrower. We were, however, unsuccessful in determining the presence of the biciliate orange gametes (?) described by Berthold. This failure on our part, however, may be due to an entirely different cause, which we now suggest.

Berthold's view that the large, dark green swarm-cells are ova, and the orange swarm-cells sperms, seems scarcely conclusive, not only from the nature of his experiments, but also from Went's assertion that the larger cells can germinate alone. On the whole, the balance of evidence would seem to be in favour of the ordinary "sporangia" being asexual, whilst the "sporangia" containing the orange micro-spores are, in all probability, "gametangia," forming gametes. Why, then, the difficulty of obtaining cultures from these gametes? We suggest that the plant is becoming apogamous, and that, although the gametangia are formed, and although the gametes are developed in some cases, and may escape from the gametangia, still that they may be sterile. On the other hand, the gametangia may regularly, after reaching a certain stage in development, become vegetative and be transformed into adventitious buds. We have

never seen the larger sporangia so transformed, and venture to think that Went was in error in believing that that was the case. Certainly his figures lend no support to that view. Went considers this vegetative development of the sporangia as abnormal. We think, however, that the phenomenon is a perfectly normal one. It was observed by Went, in 1880, in plants obtained in the Gulf of Naples, and almost every plant which we examined from the Isle of Man, under different conditions, 20 years later showed these adventitious buds. On Pl. II., figs. 4, 8, 9, and 12, we figure some stages in the development of these vegetative buds, and at fig. 6, one of them isolated (naturally), evidently in the preliminary stages of forming a new plant. Further observations are, however, desirable on this point, observations which we hope to carry out later in the year. We may add that we never saw any evidence whatsoever of the presence of a gall-producing rotifer; in all cases the contents of the filaments and the sporangia were perfectly normal. Possibly it may be in the power of some worker at the Biological Station at Port Erin to follow out this subject, and, by determining accurately the fate of the mega-spore and of the hypothetical gametes, finally settle the problem, and so add the last chapter to the life-history of one of the most interesting of our British Chlorophyceæ.

Explanation of Plates.

Plate I.

Fig. 1. A small plant of *Codium tomentosum*. Nat. size.

Fig. 2. Rhizoidal filaments, in some cases attached to and enveloping grains of sand. × 350.

Fig. 3. One of the palisade "cells"—narrow mucronate type. × 350.

Plate II.

Figs. 4, 8, 9, 12. Various forms of vegetative developments from the abortive gametangia (?). × 350.

Fig. 5. A "palisade cell" with one empty, one full ripe, and one developing sporangium. The same cell bears the scar of a fallen sporangium, or possibly, from its position high up on the cell, a gametangium. × 350.

Fig. 6. An adventitious bud after its isolation from the parent "cell." × 350.

Fig. 7. Gametangium (?) in process of forming a vegetative bud. × 350.

Figs. 10 and 14. Stages in the development of the plug-like septa. × 600.

Fig. 11. A medullary hypha of a young plant, showing mode of origin of the lateral "palisade cells." × 300.

Fig. 13. Apices of "palisade cells," (*a*) *C. galeatum*, (*b*) *C. mucronatum*, var. *tasmanicum*, (*c. d.*) *C. tomentosum*, (*e.*) *C. mucronatum*. *c. d.*, × 550; *a. b. e.*, after Agardh.

Plate III.

Fig. 15. A ripe sporangium. × 350.

Fig. 16. Apex of ripe sporangium, showing apical cavity and lamellated inner wall. × 800.

Fig. 16a. Zoospores after escape from sporangium. The spot in the hyaline apex probably represents the nucleus. × 550.

Figs. 17 and 18. Palisade cells with lateral sporangia. × 350.

Fig. 19. Vegetative budding of one palisade cell from another. × 350.

Fig. 20. Base of a ripe sporangium, showing the plug, the basal cavity, and the mode of separation of the sporangium. × 350.

Fig. 21. Longitudinal section of the thallus, showing the relation of the medullary hyphæ to the palisade cells. × 60.

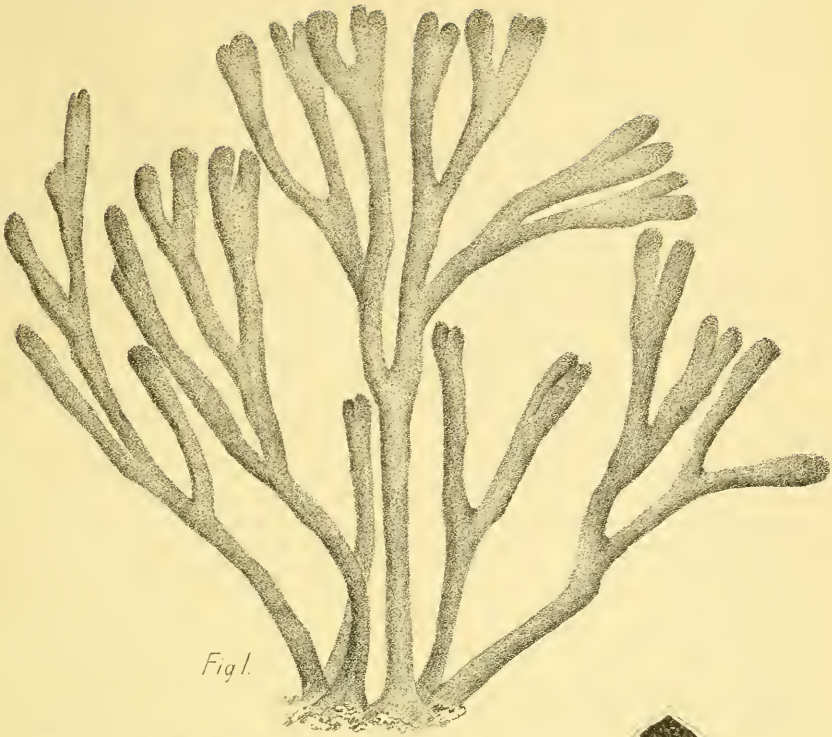

Fig 1.

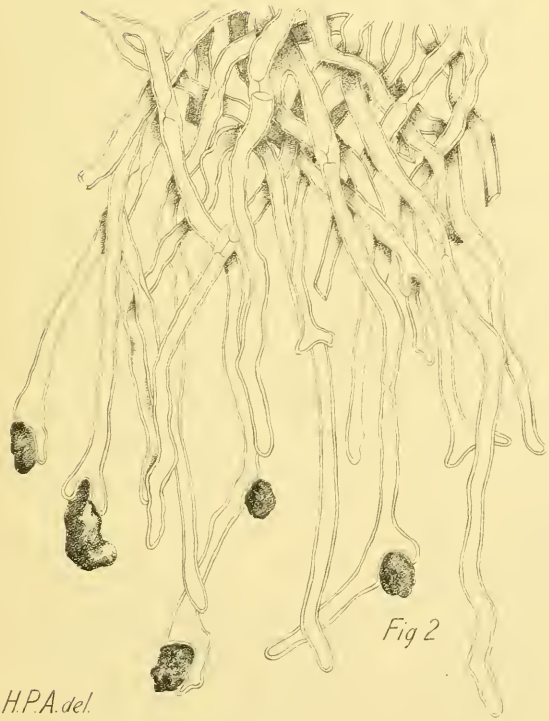

Fig 2

Fig. 3.

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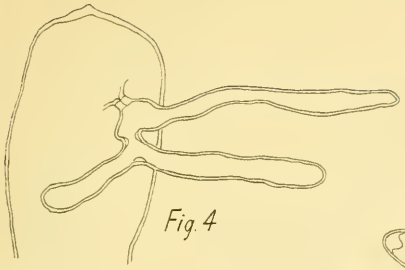


Fig. 4

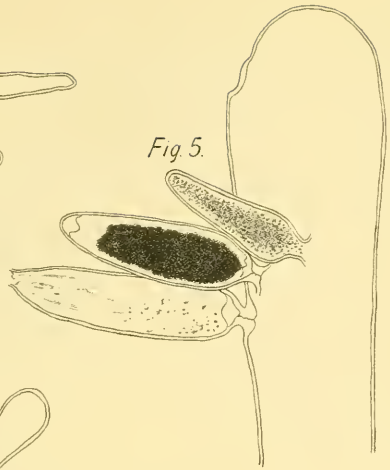
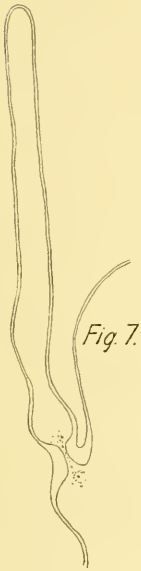


Fig. 5.

Fig. 6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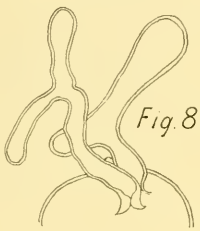


Fig. 8

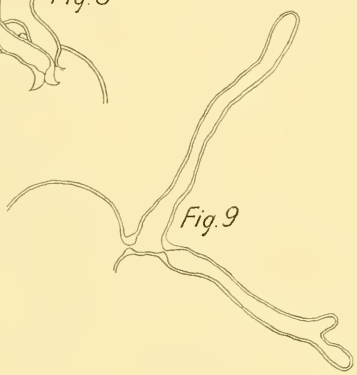


Fig. 9

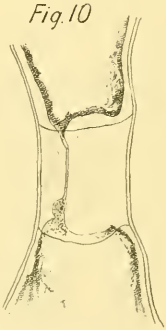
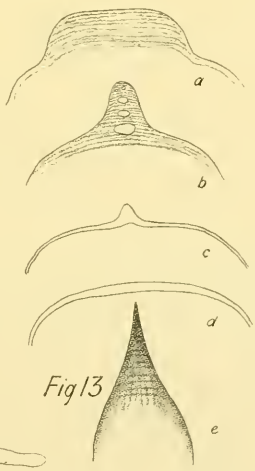


Fig. 10

Fig. 12


a
b
c
d
e
Fig 13

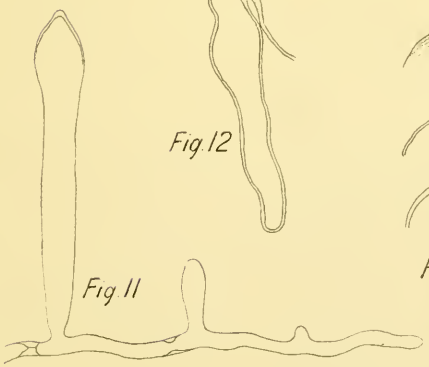


Fig. 11

Fig. 14.

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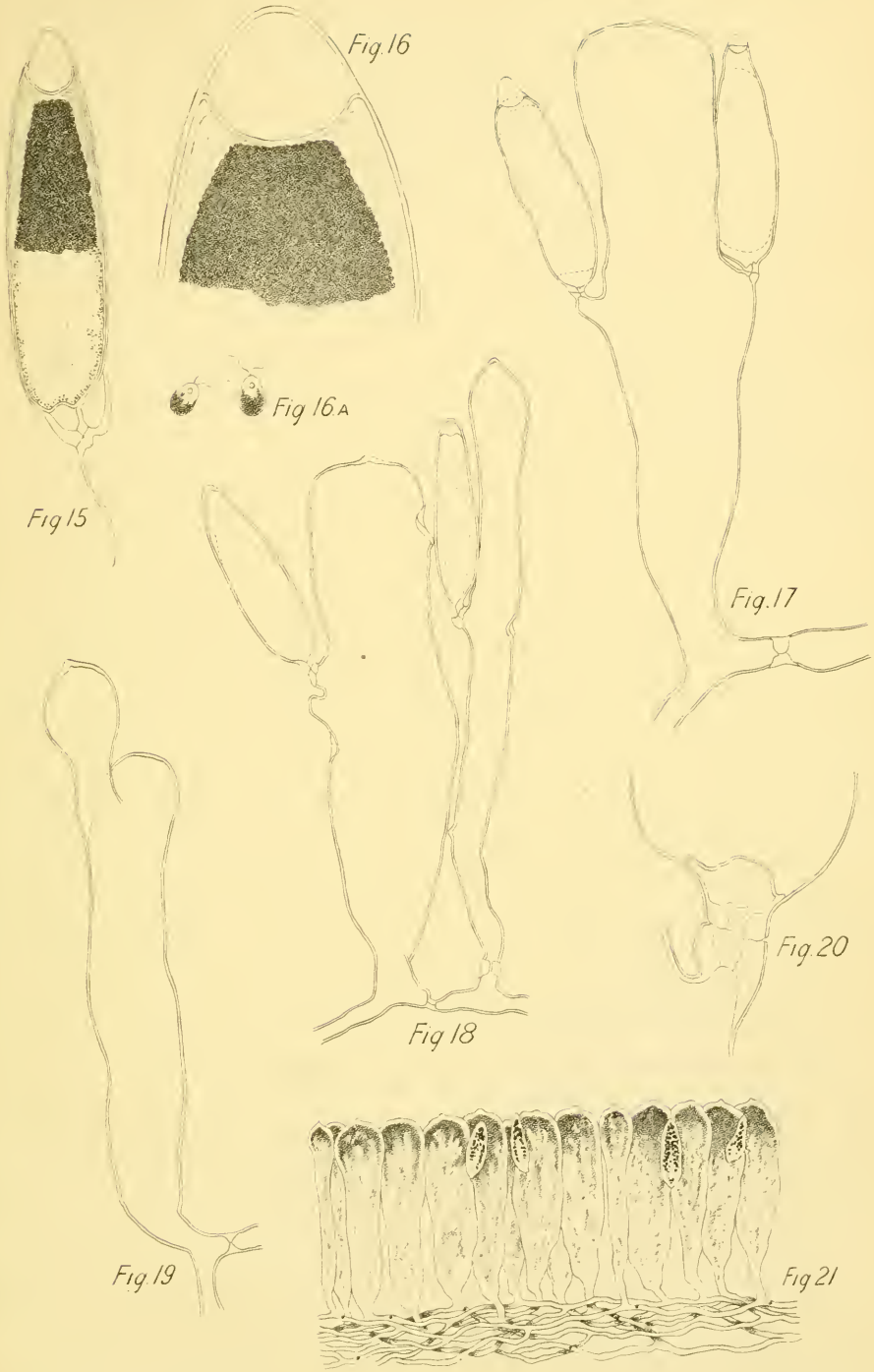
Fig. 16
Fig. 16A
Fig. 15
Fig. 17
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